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Industrial Engineering - James L. Lundy, University of Minnesota, Minneapolis, Minnesota.

Petroleum Engineering - Fred Gitzendanner, Associate Director of Engineering Research Department, Standard Oil Company, Whiting, Indiana.

If any of our readers have further suggestions as to what fields we should cover they will be gratefully received.

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CAPITAL EQUIPMENT AND REPLACEMENT POLICY IN THE PETROLEUM INDUSTRY

by

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Well developed methods are available for analyzing capital investment proposals such as are represented by the replacement of existing facilities. These methods are rationally sound. In general, they all utilize in some form the concept of desired rate of return. Some of them, like the MAPI formula, introduce desired rate of return or cost of money into the calculations in such a manner that the results of the calculation is an indication to either accept or reject the proposal. In other methods, the rate of return is calculated as the "answer." This "answer" is then compared with the company goal and the decision to accept or reject the proposal is quite automatic.

The object of this paper is to discuss the place of desired rate of return or cost of money in such calculations and second, to indicate how these concepts are utilized in the petroleum industry.

All business is basically alike with respect to capital investment. That is, it invests capital in the hope of making a profit. Successful businesses do mak a profit but there are enough which do not to keep managements ever mindful of the fact that profit is not an automatic accompaniment of being in business. This fact creates a strong drive for the development of methods of investment analysis to give managements the best possible picture of the probable profitability of a proposed investment. The MAPI and similar

methods are the result of this drive.

It is interesting, however, to note that most businesses are launched without benefit of much in the way of precise, or what might be called rational, investment analysis. Usually the vision, energy, faith and courage of the founder or, at most, of a few associates are the basis for launching a business enterprise. Only after an organization has functioned for a time does it begin to use the more sophisticated and precise methods of investment analysis which are available. The "faith and hope route" is hardly to be recommended as the best method for investment analysis, but it is worth bearing in mind that many vitally important decisions are made without using highly developed investment return analysis methods.

Capital equipment investment, however, is a continuing process. Each business is founded only once and even the strongest supporter of the merits of horse sense soon uses some other method for appraising the attractiveness of new equipment investment proposals. Payout, rate of return, present worth, and equivalent annual costs are some of the methods used for calculating the profitability of an equipment investment proposal. These methods have the shortcoming of treating all types of equipment alike as to required rate of return. To be sure, when the analysis and calculation is complete, judgment can be exercised as to the broad category of risk and hence reasonable rate of return which might be expected from various types of investment. However, this approach has the inherent weakness of according only incidental emphasis to an important point.

A somewhat more rational approach to the problem involves classifying equipment purchase proposals into different classes in accordance with the risk inherently associated with them. Different expected rates of return are then established in accordance with the

economic risk inherently associated with each class. For example, in the oil refining business equipment in a refinery power station is more likely to operate in its planned manner and be less subject to technological obsolescence than processing equipment such as, for example, the newest type of catalytic reforming unit. The power plant equipment representing less business or investment risk can be expected, in the economic sense, to earn a lower rate of return than the process equipment.

It is a form of financial heresy to suggest that a different rate of return should be expected from one piece of equipment than from another. And with good reason--they are all competing for the same investment dollar. On the other hand, the recognition of the fact that they do earn at different rates merely recognizes life as we all know it to exist--no matter how much we may resist stating it in concrete terms in a financial analysis.

To ignore the fact of different rates of return leads to costly difficulties. An investment may not be made in low-risk low-earning areas on the ground that the funds can be more profitably utilized elsewhere. For example, in a given situation, investment in process cooling water facilities may be low-risk low-earning and as a result the new investment may not be made. Ultimately, the new equipment might be differentially so profitable that it could compete for the funds which, in high-risk areas, earn high rates. The investment would then be made in the new equipment to replace the old. However, in the meantime operating costs have been high, and if competitors have been willing to invest in low-earning cooling water facilities, the company may have been operating at a serious competitive cost disadvantage.

This concept of different rates of return to be expected from

different classes of assets is particularly important to a firm which has just established an average rate of return for use in investment analysis calculations. Once a firm has threaded its way through the pitfalls, blind alleys and general confusion to arrive at a reasonable average rate of return to be expected from investments in equipment, it is likely to feel that it has reached its ultimate goal. Actually there is an additional objective to be attained: establishing reasonable rates of return for various classes of equipment.

Therefore, to summarize my first point, I suggest that methods for analyzing equipment investment proposals must recognize that different classes of equipment earn different rates of return depending upon the inherent economic risks associated with them and with competitive conditions in the industry relative to them.

Discussing the investment analysis practices of the petroleum industry is akin to the four blind mens' descriptions of the elephant--it depends upon where you stand as to just what you see. The briefest description is to say that the petroleum industry uses these methods and that it does not use these methods. Rather than leave the discussion in this obviously unsatisfactory state, I shall instead describe the problem as it exists in the petroleum industry and discuss common practices with respect to the different facets of application.

In order to keep this discussion within reasonable bounds and in order to discuss things along the line normally thought of as equipment investment and replacement, I shall talk about the refining, or as it is more commonly known in the industry, the manufacturing phase of the petroleum industry.

As to where this term fits in the petroleum picture, the

industry consists of four major phases. Production--which includes finding and bringing crude oil to the surface of the ground; transportation--which carries crude oil to refineries and petroleum products from refineries to markets; marketing--the function of wholesaling and retailing petroleum products into every corner of the country; and manufacturing--which transforms crude oil into over 2,000 petroleum products. These processes have changed so much from the original simple distillation steps and now include so many processes which are essentially chemical manufacturing in nature--and this does not refer to the petrochemical branch of the industry at all--that the term "manufacturing" has become common usage in the petroleum industry.

One characteristic of petroleum industry manufacturing is that specific pieces of equipment are seldom replaced in kind by another piece of equipment to perform the same service. Once a complex refining unit is installed and operating satisfactorily, it is rare that a new type of equipment appears which is enough better than the original, if the original works satisfactorily at all, to warrant replacing it. This is in contrast with many cases such as machine tool replacements where new equipment commonly appears which is sufficiently better in performance and economy to warrant replacing the old.

Therefore, since the equipment replacement problem seldom arises, methods of analysis such as the MAPI and similar formulas are practically never used. This might suggest that petroleum refining is a small purchaser of new equipment; however, for the last nine years the industry has spent over 500 million dollars per year for new manufacturing equipment. Standard Oil of Indiana in the same period has spent an average of $47 million per year for such equipment.

In spending this amount of money for new equipment, a great number of individual cases arise. These originate at many places in the organization and evaluation procedures have been standardized to the point that certain specific questions are covered in each proposal. It is not common in the industry, however, for these proposals to be accepted or rejected on the basis of a rather rigid comparison with a stipulated desired rate of return. The reason for this will be discussed later.

The great bulk of new equipment and replacement expenditures in petroleum manufacturing result from a lengthly and complex process. In the manufacturing phase, the petroleum industry is characterized by keen quality and price competition, heavy capital investment, long term growth and extreme technological complexity. The resulting planning problem is handled by various companies in different ways.

In Standard of Indiana, for example, the senior executives of the company periodically assign major problems to be studied. These assignments are made to various groups in the company and the results of the various studies are then coordinated into an over-all company plan.

Normally a study starts as a two-pronged attack. The first is addressed to raw material availability, the second to market demand.

Crude oil, or raw material, availability is of obvious importance. It is essentially dependent on man's ability to find nature's hiding places for oil. Despite the obvious difficulty of accurate forecasting in this area, it is so important that major effort is devoted to it. The methods and results of that extensive work, however, are not particularly pertinent to this discussion.

If fathoming nature's secrets is difficult, predicting man and

his market behavior is perhaps more so. Here three aspects of the problem must be coordinated.

The technical people who have been following the trends in automotive engine development, oil burner design and the myriad other places in which petroleum products are used must firm up their recommendations as to product type and quality requirements for the future. Simultaneously, the general economics people are continually studying indices of general business, the manufacture of automobiles, trends in use of trucks and tractors, highway construction, home building and all of the other available indices of general economic conditions. From this they prepare their economic appraisal of the future. Third, the sales people in the various sales territories are preparing their forecast of their ability competitively to obtain business in terms of the sales territory picture as they see it. These three phases of the market picture are integrated into a company sales forecast.

From these over-all data, various possible alternatives for reaching the quality and quantity goals must be devised and explored. This is a lengthy, complex and detailed process. In some instances, relatively simple modifications of existing refining units will remove bottlenecks or will enable them to be modified to meet new requirements. In other cases new processes and major units must be developed and constructed. This type of study is a never-ending task and it is impossible to say how long a given piece of it will take for completion. Some phases of the problem will have been under study for extended periods or even continual study such as, for example, catalytic cracking research, whereas others might be crystallized quite rapidly.

At this point, the reason for the absence of a rigid rate of

return goal against which investment proposals are measured becomes evident. The market and raw material forecasts necessarily involve long-range projections. They include many areas in which the data are less than precise. Many of the key decisions hinge on intangibles. In such a circumstance, even though a specific rate of return calculation can be made in terms of the estimates, it is pointless to impute great precision to data which are inherently not precise. This, of course, is an infirmity not only of rate of return calculations. It is inherent in all methods of investment analysis which involve long range forecasts. As a result, it is recognized that judgment of a high order is required to select sound investment proposals. It is also recognized that such a caliber of judgment does not result from undue emphasis on a fixed rate of return goal.

All along the line so far discussed, economic appraisals are made. Early estimates are rough and as more data become available they are sharpened up. Ultimately a project which is past all hurdles reaches the design stage. At this point the basic economic goal changes somewhat. The goal now becomes to minimize capital requirements. There are always more places to put money than money to put. This is a rather common situation in industry generally.

The oil industry is in the same difficult position as most other industries. The cheapest plant to build is far from the cheapest plant to run. Therefore, it is continually necessary to trade capital investment for operating economy. At this stage most of the business intangibles have been eliminated from the consideration and straightforward technical and economic analysis is possible. Therefore, at this point some semblance of uniformity in rate of return requirements for justifying additional investment begins to be felt.

Methods of analysis used cover a wide spectrum of the commonly

recognized procedures. The simplest and oldest, of course, is payout. This method, however, is steadily losing favor because of its obvious drawbacks when comparing alternatives having quite different patterns of expense and income with time. As I indicated earlier, the MAPI and similar formulae are practically never used, not because of objections to them as methods, but rather because the problem practically never arises in the terms of those formulae. The general trend is toward the calculation of some form of rate of return. As you probably know from various articles in the literature, names such as discounted cash flow rate, investor's mthod, profitability index, to name a few, have come into use. Regardless of name, however, each of these is some form of the long-understood rate of return. In some instances, it is merely compared with the company's historical average rate of return, in others it is stated as a multiple of it. There is ample room for further work and understanding in this field.

Thus, to summarize, it seems clear that rational and specific methods of investment proposal analysis are available, they are here to stay and they add immeasurably to the understanding of situations which otherwise would be dependent entirely upon hunch. It is characteristic of them that they utilize the concept of cost of money or desired rate of return.

The use of single rates of return if relied upon too heavily can lead to unfortunate results. A preferable method would be to establish rates of return for different classes of equipment, these rates to more nearly reflect the economic risk and competitive situation associated with them.

The petroleum industry, as a large purchaser of new equipment and as a technologically and scientifically sophisticated industry, would be expected to use the investment analysis methods which are available.

The petroleum industry does use such investment analysis methods. It does not, however, use stipulated rate of return criteria to anything approaching the extent that they are used in many other industries. It seldom faces the problem of replacing equipment in kind to continue to perform the same function. Thus investment analysis problems it faces are in different context and relatively rigid rate of return criteria would not be conducive to the exercise of the freedom of judgment it has found effective.

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Presented at Cost Control Conference, Illinois Institue of Technology, December 6, 1956.

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*THE FAILURES OF ECONOMICS: A DIAGNOSTIC STUDY

Review Article

by
Rudolf R. Rhomberg
University of Connecticut

One need not agree with the main argument and the conclusions of a book to benefit from it. It is likely that economics, and the social sciences in general, will gain from any controversy that may be induced by Schoeffler's Failures of Economics, though many of its theses may finally be rejected, at least in the extreme form in which the author has chosen to put them.

The largest part of the book consists of a critical evaluation of the methods used in economics and includes an impressive list of methodological sins commonly committed by economists plus one hundred pages of case studies. This critical part of the book culminates in the conclusion that "economics is not a nomothetic, empirical science" (p. 155). In fact, "it seems that 'economic science' has the rather strange characteristic that whenever it is 'economic' it is not 'science,' whenever it is 'science' it is not 'economic,' and quite frequently it is neither" (p. 154). This last statement provides some welcome comic relief and also an interesting logical exercise, namely whether it is possible--and no doubt it is--to find a definition of "science" and one of "economic" such that the two concepts are incompatible. Apparently having found a suitable pair of definitions Schoeffler concludes that economics is an art, in particular it is the art of formulating economic policy. It is unlikely that many economists will be particularly disturbed by

*Since so many of the ideas propounded in this book apply equally well to Engineering Economics it is believed that the review of the book will be of great interest to Engineering Economists.

The Editor

by this matter of classification and definition, at least not until someone charges that "economic art" is not "economic" when it is "art" and that it is not "art" when it is "economic."

Of greater importance are the author's substantive points in this context. He maintains that economics cannot discover empirical laws within the economic system. The reason for this inability is that our economic system is not a closed system, i.e., one in which the values of all variables are determined within the system (endogenous variables). An example of such a system which is not subject to the influence of variables acting upon it from the outside (exogeneous variables) is the solar system, assuming no disturbance from outer space. Nor is an economy a semi-closed system, i.e., one that contains some endogenous variables, but is subject to disturbances by exogenous variables. An example would be a thermostat system, the outside temperature being the exogenous variable. Rather an economic system is an essentially open system, i.e., one that does not contain even a single endogenous variable, not a single "universal law-of-nature" relationship. Being concerned with an open system economists cannot discover unconditional "laws[1]/," they cannot predict successfully, economics is--to date--a failure. In their futile attempt to remedy the situation by orthodox means economists have fallen into a number of methodological traps. To list a few at random, "they artificially simplify," "artificially generalize," "artificially isolate," "artificially close," "artificially semi-close," "they assume the heterogeneous to be homogeneous,"

[1]/ Schoeffler insists, p. 129, that by "law" he means only absolutely unconditional laws. Since there are no (or almost no) empirical laws corresponding to that description, the category is empty (or almost so). Economics may then welcome the art of chemistry, the art of physics and others into the group of the empirical arts.

etc. (p. 40), in all, 18 types of error.

Now, there is no denying that the success of prediction in economics has not been spectacular, although it is undoubtedly improving. This admission is one thing, but it is quite a different thing to be told that with the traditional methods the predictive batting average cannot possibly be improved. It may be interjected here that the author apparently approaches his topic as a pure logician (see below) rather than as a person acquainted with the practical aspects of the scientific method. At any rate, the study betrays a rather naive belief that the natural sciences deal with sets of entities that form closed systems or at least semi-closed systems while the social "sciences" are confronted with open systems. The fact of the matter is that we are in any field confronted with a set of entities to which we apply certain mental processes. In this fashion we create a system and we close the system as much or as little as we find it convenient to do for the purpose at hand. There is only one instance where such closure does not result in an "error" in Schoeffler's sense, that is when we are considering the universe as a whole, including all the stars, their planets, moons, the eystrain of the astronomer, what he had for supper, etc. Whenever we consider a subset of entities, closure of the system amounts to a formal error leading to possible errors in prediction if the prediction is made in unconditional form.

Apart from closure and semi-closure of systems, the history of the natural sciences is full of accomplishments achieved with the help of Schoeffler's methodological "sins", properly applied. His error lies in believing that we can have complete knowledge (and thus unconditional prediction) in the natural sciences and no systematic knowledge at all in economics. In fact, our knowledge

in any of these fields is always more or less approximate, the desired degree of approximation to some extent determining the choice of methods, i.e., the degree of simplification, isolation, etc. which is appropriate under the circumstances. To be sure, each of these methods may be misapplied, each may be the source of error. One merit of the book lies in the excellent description of these possible pitfalls.

Again, it must be admitted that there are among the empirical sciences apparent differences of degree concerning the efficiency in prediction, economics and meteorology being less efficient than chemistry and astronomy. The reason for these apparent differences is, in part at least, that the economist and the meteorologist have traditionally tackled more ambitious tasks than the chemist or the astronomer. But while the difference in predictive efficiency between the economist and the astronomer may be substantial, it is probably quite moderate as between economics and some of the other natural sciences (or "arts"). However that may be, incorrect predictions in all sciences serve a useful purpose by inducing a revision of the underlying "model" or system, say, by inclusion of an additional variable formerly unknown or believed of negligible importance. This is the process by which astronomers discovered the planet Pluto and by which economists after World War II discovered the importance of the level of liquid assets as a determinant of consumer demand.

Schoeffler concludes the critical part of his study by reoommending that economics should divide its field into three areas: (a) general decision theory, an independent area of study in cooperation with logicians, engineers, statisticians, etc.; (b) economic policy-making, the "art of economic 'healing'" (p. 153); and (c) economic

history, or ideographic economics, i.e., description in the fields of labor, national income accounting, public finance, etc. Furthermore, all economists should concentrate more on methodology. Of course, fields which do not exist, such as economic theory, need not be pursued.

There arises the interesting question what general principles the economic "doctor" (b. above) should use as a basis for his art. What performs for him the function that medical science performs for the medical practitioner? The author answers that the economic-policy makers "should become acquainted with the findings of general decision theory and should get to know the results of social psychology, sociology, jurisprudence, technology, demography, geology, and other disciplines relevant to their task...and the relevant findings of the ideographic economists" (p. 163). But here Schoeffler puts us into a difficult position: If there are no principles ("laws," regularities) in economics for the reasons given in his book, then it is almost certain that, for the same reasons, no such principles exist in sociology, jurisprudence, social psychology and other social sciences. In fact, the economic doctor could only draw on the law of gravity, (e.g., when making such observations as: "With a heavy heart I note the increase in unemployment"), perhaps on the law of diminishing returns, and other more or less stable relationships discovered by the natural sciences. Unfortunately, economic history and other ideographic subjects will be of no assistance to him since without underlying principles history consists only of raw data. This is indeed a dismal picture of the future of economics. However, this reviewer does not feel unduly alarmed for the following reason: The logical result of Schoeffler's study, namely that economics is strictly speaking impossible, is implied in the notion that precise knowledge is, strictly speaking, impossible. This was known

already to Socrates who said he knew that he did not know anything. This basically healthful awareness has not unduly hampered scientific progress to date and this reviewer is confident that it will not do so in the future; (to be on the safe side, let us add "other things equal", although this constitutes, I believe, "artificial fixation" or "artificial semi-closure," or both).

So much for the critical part of the book. There follows, after the chapter labeled "Conclusions", a final chapter titled "Prediction in Economics" which sets forth the author's recommendation concerning the method to be used by the economic doctor. After the elaborate demonstration of the failures of economics in 16 case studies, exemplifying practically all economic research, the reader approaches this last chapter with eager curiosity, but he is likely to find it somewhat disappointing, perhaps because his expectations have been raised too high.

According to the author, economists have made the mistake of pursuing their subject matter with the help of methods designed for use in the natural sciences. With those methods they have also adopted the concept of prediction as used in the natural sciences. This could not but lead to frustration of their efforts. The belief that no other, more suitable, methods are available is mistaken. Schoeffler then presents an outline of a model for "prediction" as applicable to the social sciences consisting mainly, as the author explains, of an adaptation of parts of Professor Rudolf Carnap's work in logic and semantics. The method may be briefly described.

First, on the basis of available information collect all the variables relevant to the problem. (We might comment here that in practice this step will probably amount to "artificial closure."

We note that in the critical part of the study Schoeffler comments: "...the difficulty arises in the attempt to specify the complete set of all relevant variables; the number of these variables may be astronomical," p. 24). Second, make a list of all the possible states of the system, and their probability distribution, each state being a different possible combination of values of the variables. Furthermore, make a list of all the possible histories of the system, i.e., all the logically possible successions in time of the possible states, and the probability distribution of these histories. Third, with the help of the available information remove all states and histories from the list which have probabilities of zero. "Information" includes only confirmed laws (static or dynamic) and observations of states or histories. Fourth, predict. That is to say, read off the histories and their probabilities remaining in the set, after removing all those impossible in the light of information. This reduced list constitutes the only prediction possible if the forecaster wants to avoid overstepping the limits imposed by the available information.2/

The apparatus is unwieldy, to be sure, but it is foolproof. It is of the "just-add-water" type, provided the necessary IBM computers are available. This model is, of course, not a new method of discovering truth, it is just a rigorous method of avoiding incorrect predictions and as such it may have its merits. But it is important to note that it does not accomplish this by making a specific forecast more probably correct, but by preventing the forecaster from uttering such a specific forecast in the first place,

2/ In the appendix (a reprint of the author's article "Toward A General Definition of Rational Action," Kyklos, 1954) a similar, but more complicated, model is applied to a problem in decision theory. Some of the following comments apply to that model, too.

in accordance with the Latin proverb: "If you had remained silent we would have held you to be a wise man." What the author seems to have overlooked is the relation between the first step, the selection of variables, and the range of the prediction. Unless the number of variables is radically limited ("artificial closure") the forecast will be, that almost anything can happen (though some outcomes are more likely than others).

From the point of view of what has been said above about the function of incorrect predictions in the progress of science one may even doubt the merit of a method that eliminates these errors. Working with that model astronomers would not have discovered Pluto by accounting for the deviations in the observed orbits of the eight planets then known from their theoretically expected orbits by the hypothesis of a ninth planet. Only through artificial closure of the model to comprise eight planets, no comets except negligible ones, etc. could expected orbits for the known planets be computed in the first place.

There is the additional difficulty of the information to be used in the third step of the method. If that information is to be limited to the confirmed findings of technology, geology, demography, etc. and to frequency distributions of events observed by economic historians, the model is likely to be so barren as to be worthless. For that matter, even the inclusion of the historical information of the frequency distribution type seems to involve "artificial fixation," i.e., the assumption--inadmissible according to the first part of Schoeffler's study--that certain structural elements of the universe will remain constant. To be sure, the resulting emptiness of the prediction is not the fault of the model, but is due to Schoeffler's negation of economic principles and to the fact that

he rejects "artificially semi-closed" systems as tools of analysis and prediction.

These comments are not designed to deny that the model may occasionally be of value as a supplementary method. But the author has not been able to convince this reviewer (1) that the methods now used in economics are ill-designed for that field of study; (2) that this is so mainly because there is a difference in kind, rather than one of degree, between the social sciences and the natural sciences as far as openness or closure of the respective systems is concerned; (3) that the model for prediction presented by the author constitutes a new method differing in essential respects from the methods mentioned under (1); and (4) that this model promises to be a method particularly suitable to the social sciences and that it will enable the social scientist to conduct his research without resort to the various "artificialities." Rather, the reviewer holds that progress is promised by the traditional method of making assumptions, formulating hypotheses and testing the hypotheses. Testing leads either to rejection of the theory (hypothesis) or to its acceptance on a provisional basis until a superior theory replaces it. The forecaster can do not better than to draw on the body of currently accepted theory. This is a manageable and eminently practical method. The search for absolute truth must remain an illusion.

Nevertheless, economists and social scientists will find in this volume much to stimulate further thought, study, and perhaps controversy. The Preface states: "My hope is, quite sincerely, not that my theses be accepted as they stand, but that they will induce other people to investigate further" (p. VIII). There is no doubt in this reviewer's mind that the author has achieved this objective.

The Failures of Economics: A Diagnostic Study

By: Sidney Schoeffler

Harvard University Press, Cambridge, 1955. Pp. XIII, 254
Price: $4.75

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MACHINE COST FORMULA

Review Article
by
Fred D. Stone
Stanford University

Realf Ottesen, in his article in the November 1956 issue of Mechanical Engineering entitled "How to Analyze the Cost of a Machine Tool from a Swivel Chair", reduces to a formula the complex and difficult problem of determining a machine tool's hourly costs. This formula is presented to aid in making decisions such as (1) "What machine is the most economical?", and (2) "What price level has the tool to be loaded with for no profit and with certain profit conditions." The main motivation behind this mathematical development is to place such decisions on an objective instead of the usual subjective basis. The criticisms which ensue in this review are mainly directed towards the applicability of the author's approach in reference to a replacement decision. In reference to decisions of the type (2) which involve the theory of pricing, it is sufficient to state that more than just the costs incurred by a machine's operation must be considered. For instance, in the determination of a price, other factors like market acceptability and capacity, present and future product competition, the product's economic life, and the company's financial position and policies must be evaluated. The author in his analysis has denoted only one of the many factors necessary to a successful pricing policy.

For ease of calculation, the formula's solution is reduced to nomographs. Thus, the equation's solution is easily and quickly obtained by drawing a series of straight lines. This approach requires no knowledge of mathematical manipulations. The use of a

nomograph is indeed an admirable aspect of the author's approach. For illustration and explanation purposes, the mathematical symbols which are contained in the formula are replaced by word descriptions of the cost factors involved. The formula as illustrated in this manner is given in Figure 1.

machine's hourly cost = capital recovery costs + repair costs + space costs + labor costs + electrical costs

Figure 1.

Contained with the description of each of these cost factors will be the reviewer's comments and criticisms. (These, as previously stated, are mainly relevent to types of replacement decisions.)

1. Straight Line Depreciation plus Interest on First Cost: This term yields an approximation of the cost of capital recovery. When the salvage value is very small, this approximate method overstates the cost of capital recovery. To counteract this tendency, the author multiplied the interest by a ratio of 2/3. This particular value was derived from "experience". Because the effect of a sizeable salvage value was never considered, the method of applying a set factor, such as 2/3, might lead to an understatement of capital recovery costs. To combat this, as the salvage value increases, the ratio used to reduce the interest must decrease. It appears advantageous to point out that the exact annual cost of capital recovery can be obtained by other means which present little, if any, additional difficulty or calculations.

The author states that whether external or internal company funds are used, interest must be paid for the money's use. The desirability of using one source of funds instead of another is dependent on the company's financial position, market conditions, Federal Reserve Policy, etc. It is impossible in this short review

to give further consideration to this complex problem. However, it is felt that elaboration is needed to determine whether a company is receiving maximum use from its funds if they are allocated for replacement. Every desirable investment opportunity must offer a return on the funds invested. To obtain maximum use from the available funds, the investment having the highest rate of return or profitability is appropriated funds first and so on until a limit is reached. This limit is established through a consideration of the company's financial environment and policies1/. Replacement investments must be justified on this basis along with all other investments. The foregoing sentences sketch briefly the approach involved in determining if funds should properly be used for replacement.

Nowhere in the article is a clear differentiation made between the application of this formula to an existing old machine, instead of a new one. If the equation is employed in relation to an existing asset, the present market value or value to the owner is to be applied. In such cases, the initial investment is properly termed as a sunk cost. Sunk cost, or past cost, is irrelevent, and therefore not included in the cost of operating an existing machine. Past costs are important only where they serve to forecast future cost patterns.

2. Repair Costs: Although the author recognizes that repair costs increase with age and use, his analysis is based on an average annual repair cost. He assumed that a good approximation of the annual cost of repairs to be a certain percentage of the initial price. By making such an assumption, the time value of money in reference to repairs is taken at zero percent. In other words, it

1/ Dean, Joel, Capital Budgeting, Columbia University Press, 1952

is neglected. Leading directly from this assumption is the implied fact that the machine's economic life is the one which extends for the greatest number of years. (All annual costs are constant except capital recovery which decreases as the machine's life increases.) However, as leading authorities on determining a machine's cost have written, increasing repair costs must be converted from one time period to another by applying the same rate of return as used in determining the capital recovery costs. If this approach is followed, a minimum annual cost point will occur, and the life at this point is the machine's economic life which should be used in a determination of its annual cost. In summary, whether the author's approximation will lead to a valid figure for the annual machine's cost is dependent on the value of the rate of return, size of the repair increases in the later years, and the period of time between these repairs. The author's approach which uses an average annual repair figure will yield a correct solution only if certain limiting and generally unrealistic assumptions are made. Such assumptions might be either that the repair costs rise insignificantly during the life of the machine, or the interest rate used is zero percent. The author has utilized the second assumption as a justification of his approximation.

3. Space Costs: The determination of the amount of space needed for the machine is accomplished by evaluating the following four factors: "(a) The space requirement of the machine itself comprising all the tool's movements in a horizontal plane. (b) Space for the machine goods awaiting their turn. (c) Space for the laborer, his tools, and tool chest, and (d) Additional part of the unused space of the factory premises, eventually proportional space of

office and all indirect space."2/ This area, besides being necessary in the determination of the floor area cost, is used as a basis of burden distribution. The approach used is similar to the allocation of burden among cost centers in cost accounting. The items applied to the machine through burden are heating, ventilation, overhead light, light at the machine tool, insurance of tool, and diversified.

However, it must be realized that only costs which cease to exist if the machine is disposed of, or are created by the acquisition of the machine, should rightfully be charged as machine expense in replacement decisions. Looking over the costs which were charged, cost arising from item (d) in the space determination, heating, ventilating, overhead light, and parts of the diversified would, in most cases, still exist if the machine was disposed of. Also, if the floor space was unusable before the machine was installed, the rent on the normally unusable portion should not be included in the machine's costs. Only incremental costs are relevant, not average or indirect expenses which are allocated by accounting methods. Confusion and non-recognition of incremental costs arise when a cost accounting viewpoint is pursued in the allocation of indirect expenses. Following such a viewpoint generally causes upkeep to be greatly overstated.

4. Labor Costs: With these costs, a very thorough job is done of considering the various costs which properly belong to labor expenses. The labor costs considered are direct, indirect, and unproductive hourly wage factors. Although implied in the article, it seems worthwhile to restate that if the laborer does several jobs,

2/ Ottesen, Realf, "How to Analyze the Cost of Machine Tools from the Swivel Chair", Mechanical Engineering, Vol. 78, No. 11 (November 1956), page 1004

only the percentage of time spent on a particular job is charged to that job.

5. Electrical Costs: In the mathematical development, the correct incremental approach is used in determining the specific costs of electrical energy. The magnitude of the electrical charge will depend on the type of motor, time of day it is used, power requirement, and utility rate scheme.

In conclusion, it appears that the author has attempted a complex task, from which has come some fruitful ideas concerning a mathematical approach to finding the cost of a machine tool, and in reference to the use of nomographs in an equation's solution. Besides the various parts of the equation which were examined and criticised in this review, nowhere in his analysis has the author considered the possible effects that obsolence might have on a replacement decision. This is by far the knottiest and most complex problem. Joel Dean in Capital Budgeting, George Terborgh in Dynamic Equipment Policy, Eugene Grant in Engineering Economy, and authors of other leading textbooks have made attempts to set procedures and models which include a consideration of obsolescence. With the very rapid technological advancements being made today, it is virtually impossible to make a valid replacement decision with a technique which contains no consideration of the effects from obsolescence.

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DYNAMIC FACTORS IN INDUSTRIAL PRODUCTIVITY

Review
by
James L. Lundy
University of Minnesota

In his book Dynamic Factors in Industrial Productivity, Mr. Melman divides his presentation into four parts. In the first three of these he considers a study of the following three hypotheses respectively: "First, the degree of mechanization of production has been controlled by the alternative cost of labor and machinery. Second, the productivity of labor is, in turn, determined by the type of production methods used. Third, a rising proportion of industry's man-hours have been used for business management. This has limited the gains in output available per person in industry."

Part IV, entitled "Implications of the Productivity Process," proves to be the best written portion of the book. In this section attention is given to a general discussion of the nature and results of increased productivity.

Regarding the first hypothesis Mr. Melman concludes that "...the mechanization of production methods was, in fact, accompanied by a rise in the cost of manual labor as compared with machine operation." The author himself points out that high correlations do not signify causal relations, however, he proceeds to talk in terms of causation after making a statement to the effect that "...we have found that these variables are connected by a definable pattern of managerial decision-making." It also should be noted that much of his treatment of alternative costs is oriented to the number of kilowatt-hours purchasable at the cost of a labor hour, yet the cost of power is only one consideration among many when one analyzes a situation

in terms of possible mechanization or automation.

According to Mr. Melman, if the ratio of wage rates to machine costs did not change, there would be no innovations by management. To prove such an idea one would have to show that, as existing knowledge becomes more widespread, and as additional knowledge is acquired, no changes are precipitated in practice. The author treats these considerations with such brief comments as "knowledge of industrial truck design and the techniques needed to manufacture them were both available in 1938 as well as in 1950." However, he does not recognize improvements which occurred in industrial trucks and their attachments between 1938 and 1950, nor does he recognize the increasing number of individuals and companies who have and are applying the fundamentals of materials handling.

Although no quarrel exists in regard to the second hypothesis as it is stated above, an earlier statement of the hypothesis holds that "...labor productivity is governed by the degree of industrial mechanization. Labor productivity will thus be shown to be a direct function of alternative labor and machine costs." This latter statement is based on acceptance of the first hypothesis. Furthermore, if one pursues the study of alternative costs in terms of unit labor costs rather than hourly wage rates, it seems quite likely that labor productivity is as much a determinant of alternative costs as it is a result of them.

In regard to the third hypothesis to the effect that "...the growth of administrative overhead in industrial firms has limited the effect of rising labor productivity on the output of goods per person" the author points out that "the proportion of industrial man-hours used for managing has been increasing." Here again correlation rather than proof of causation poses a limitation, for what

growth there has been in productivity may have been brought about largely through extra administrative effort. In other words, should we speak of the maintenance of a purchasing department as offsetting increased direct-labor productivity or as having contributed to increased productivity by maintaining minimal inventories while keeping machines and men supplied with materials?

Although Mr. Melman's research has not conclusively proved his hypotheses, he has made a pioneering contribution in the gathering of data which eventually may become valuable. In addition to the factual material presented in the body of the report, forty-five pages of appendices may be useful to the student of the causes and effects of productivity increases.

Dynamic Factors in Industrial Productivity

By: Seymour Melman

John Wiley & Sons, Inc., New York, 1956. 238 p.
Price: $4.75

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HOW TO INVEST YOUR CAPITAL FOR PROFITS

"Some Comments"

by
John Happel
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The Criterion proposed by the author is the incremental present worth, or the increase in present cash value of a project over the total investment required. Thus it is a measure of the increase in value of assets and accumulated profits above that which would be obtained if the capital were invested in marginal projects.

In the case of an existing operation, the immediate value of working capital, tax credits and salvage is subtracted instead of the total investment. This yardstick is applicable to any economic balance, whether it be the decision to proceed with a project, the choice between alternatives, the design of equipment, or the shut-down of an existing operation.

In the opinion of this reviewer the method discussed is the most satisfactory of existing methods for economic evaluation though as Winn points out there is considerable controversy in this field at the present time. The method he outlines agrees essentially with that proposed earlier in an article by Happel (1) and designated there as the venture worth method.

That the method possesses some flexibility in use is evidenced by the difference of opinion between Winn and the writer regarding the method of determining the marginal or minimum acceptable return rate at which future profits and credits are discounted to obtain present worth. Winn suggested that it might be chosen as low as 5%, "even if there were absolutely no risks involved". For higher rates he indicates that management should fix the minimum acceptable return on the assumption that it is a function only of the relative

supply and demand for capital, eliminating consideration of risk. He then proposes to take risks into consideration by assigning appropriate contingency factors to individual elements of the economic appraisal. This is an interesting idea but it might be difficult to apply in practice, since the supply of capital cannot be readily separated from the risk which the lender must envision. The writer had proposed that a higher marginal return rate be used in evaluation of projects known to involve greater risk than usual.

Winn also comments briefly on the "discounted cash-flow" or "interest rate of return" method recently discussed in detail in a definitive article by Weaver and Reilly (2). In this method it is assumed that profits are discounted at an average rate of return, determined by trial-and-error so as to make the incremental present worth equal zero. This assumption, while avoiding the necessity to decide what value to use for the minimum attractive return rate, seems contrary to the equally reasonable assumption that profits should be reinvested or discounted at such a rate.

Optimum economic design according to the proposed method is that which yields the specified minimum attractive return rate on the last increment of investment. This concept is applicable in straightforward fashion to plant design problems. It seems to the writer that in such cases unless the specified minimum attractive rate takes possible risk into consideration, it will result in too high an investment in "optional" equipment.

Summarizing, the proposed method is applicable with varying interpretations to a wide variety of economic problems encountered in petroleum refinery and other chemical process operations. The author has presented the procedure to be employed concisely with several interesting examples.

References:

(1) Happel, J., Chem. Eng. Prog. 51, 533 (1956).

(2) Weaver, J. B. and Reilly, R. J., Chem. Eng. Prog. 52, 405 (1956).

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How to Invest Your Capital For Profits

By: F. W. Winn

Petroleum Refiner - July 1956

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INVESTMENT THEORY AND THE THEORY OF COST AND PRODUCTION
A SYNTHESIS WITH APPLICATIONS

Review
by
Paul L. Flatow
New York University

This monograph tries to synthesize a unified theory of least cost production. In addition to the usual components of the production function, the author weaves in the more complicated notions of utilization rates, replacement policy as it affects the costs of required capital services and inventory policy in its relation to costs.

The major premises of this paper fall within the orientation of econometrics rather than engineering economics. This demands that components fit into functions (frequently complex) rather than simple numerical or graphical analyses so that when, as and if the hypothesis can be stated as a mathematical synthesis, manipulation leading to overall solutions will be possible.

For example, e^{-ni} (using i as the force of interest) is substituted for the engineer's present worth factor. The approach is not new, and the ideas expressed, while pointing in the right direction, never leave the ivory tower of general hypotheses to arrive at explicit formulations.

The question then arises, is a sophisticated mathematical model a step forward when its components are essentially based on forecast estimates of salvage value, operating expense, maintenance expense, and other intangibles which, after all, are the kernel of the problem. It is rather like having an electronic brain to solve problems without a human brain to reduce the problem to a system that can be programmed into the machine.

For instance, the major premise of this paper essentially assumes a stable environment by the idea of "minimizing $w_j = \rho - \Omega_j$,

(in terms of an integral) the continuous annual equivalent of the present value of all the repair and operating expenses, and of all the net capital outlays" with respect to the period of equipment service. This assumes an infinite set of renewals of the equipment and lumps together notions of physical, economic and technological obsolescence.

In itself this is not an unusual procedure. Engineers frequently have to rely on approximations of one kind or another. In fact, it is because the real world introduces so many difficult intangibles that the engineering approach prefers to deal with discrete parts of any problem, assuming a dynamic environment, and with major variables set up so that their effects can be checked in finite time in order to adapt the technology for the optimization procedure. A primary tool is the comparison procedure, because the production world is competitive and forcibly directed toward technological improvement. All too often, for instance, a manufacturer discovers his depreciation methods are inadequate only because his competitor can make things better and cheaper. This bestirs him to think of replacement with no regard to book values.

Mr. Smith recognizes these limitations when he straightjackets his functions with linear relationships in his application. The idea of the unified theory of least cost production which would involve variables dealing with current account inputs, capital goods, utilization rates, the period of equipment service and inventory costs, is good but we have progressed beyond the stage of discerning our variables. What we need is the explicit formulation of the relationships between these variables akin to the potent methods of mathematical programming. This, the author essentially does not do, and even in his most sophisticated application,

falls back on linearity assumptions and approximating an exponential by a quadratic.

Thus, in spite of the synthesis and its departure from fixed unit costs for production inputs, we are still left with the same non-explicit formulations for marginal productivity and the like, though it may not be so obvious because they are couched in more complex language.

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